

TITLE OF INVENTION: "APPARATUS FOR FLUSHING, REPLACING FLUID AND
BLEEDING HYDRAULIC SYSTEMS"

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APPARATUS FOR FLUSHING, REPLACING FLUID AND BLEEDING
HYDRAULIC SYSTEMS

BACKGROUND OF THE INVENTION

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Field of the invention

10 [0001] This invention relates in general to the servicing of hydraulic systems and more particularly to an apparatus for flushing contaminants from hydraulic systems by recirculating the used fluid and subsequently replacing it with new fluid and bleeding air from the system.

Description of the prior art

15 [0002] Hydraulic fluid is used to transmit the pressure exerted on a motor vehicle's brake pedal to the slave cylinders provided at the wheels of the vehicle. The most commonly used hydraulic brake fluids consist of glycol-based liquids identified as DOT3 and DOT4 on the basis of the boiling points resulting from their particular composition.

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[0003] Copending U.S. Ser. No. 10/030,455, hereby incorporated by reference, discloses a novel approach for estimating the condition of brake fluid based on the discovery that moisture content is closely correlated to the copper content in the fluid.

The invention consists of a reactive test strip adapted to measure and indicate the concentration of copper ions in brake fluid in terms of a readily visible color change. The strip is immersed in the fluid and the resulting color acquired by reacting with the fluid is compared to a copper concentration-versus-color chart or to a standard color representative of the maximum concentration determined empirically to correspond to a fluid condition considered appropriate for normal operation.

[0004] Another important aspect of brake system maintenance is the corrosive nature of some of their constituents, which, upon contamination of the brake fluid, progressively contribute to damage of the metallic tubing and other parts of the brake system. In conventional brake fluids, amines are added to inhibit corrosion and prevent damage to metal parts that operate in contact with the fluid. As the brake fluid ages, its anticorrosive properties are measured in terms of reserve alkalinity; that is, the amount of amines remaining in the fluid to buffer the acidity resulting from a breakdown of the fluid constituents. Over time, thermal oxidation and volatilization produce a significant reduction of the amine content and the concurrent decrease in anticorrosive properties. Tests have shown that the reserve alkalinity of DOT3 and DOT4 fluids is reduced to about 20 percent of its original value after 18 to 20

months of normal operation. Therefore, brake fluids need to be checked and periodically replaced in order to prevent the development of potentially unsafe conditions in the brake system. Accordingly, industry maintenance recommendations are typically based on service time and milage of the vehicle.

[0005] Following the work described in U.S. Serial No.

10/030,455, it has been found that copper content is predictably related also to time and milage of vehicle operation. Thus, this correlation has similarly been used to determine the need to replace the fluid based on "virtual age"; that is, the wear and tear on the brake fluid, rather than the actual service time and/or milage. If a color change in the test strip indicates a higher-than-desirable copper concentration, the brake fluid is considered in need of replacement without further tests. This invention is described in copending U.S. Ser. No. 10/132,978.

[0006] The prior art methods for replacing deteriorated and contaminated brake fluid with new fluid are varied, however, the most common method used is a two-person operation which takes about 45 minutes to an hour to complete. Usually, the master cylinder is drained of the old fluid, cleaned and then refilled with new clear fluid. Then one person attaches a drain line to the bleeder valve of one of the wheel cylinders and opens the

bleeder valve and the other person pumps the brake pedal to move the new fluid through the system to expel the old fluid out through the bleeder valve and through the drain line into a suitable container. When the clear new brake fluid emerges from the open bleeder valve, draining of the old fluid from that branch of the system is terminated and the valve is closed. This operation is repeated for each wheel cylinder with new brake fluid being added to the master cylinder as needed during the draining operation. When the brake system is drained and refilled in this manner, it must subsequently be bled to remove the air introduced during the draining and refilling operation. This prior art method of replacing old brake fluid with new fluid has several drawbacks; it is time consuming, requires the services of two people, and uses an excessive amount of brake fluid in that the new fluid which emerges from the bleeder valves during the replacement and bleeding operations cannot be reused due to it having been exposed to system contamination.

[0007] Some of these drawbacks have been overcome by a closed system fluid replacement apparatus and method disclosed in U.S. Patent Numbers 6,206,055 and 6,302,167 to Peter C. Hollub. The Hollub apparatus includes a vacuum wand which extracts the old fluid and contaminants from the master cylinder. A fill pump is used for supplying new fluid under pressure from a closed

container to the master cylinder and at the same time a vacuum pump is connected to extract the old fluid from all of the bleeder valves simultaneously and directing it to a closed waste fluid tank. Also disclosed is the periodic shutting off and

5 restarting of the fill and vacuum pumps to produce a fluid surging to flush contaminants from the system. The Hollub apparatus does away with the need for using two-man and reduces the time required to complete the replacement operation.

However, the Hollub apparatus is not especially efficient in

10 flushing the old brake fluid and contaminants from the brake system. When the old brake fluid is extracted from all the brake lines simultaneously, the fluid will take the path of least resistance and the longer lines will often have insufficient flow to clean out the sludge and corrosion by-products. Also,

15 supplying the new brake fluid to the system while extracting the old brake fluid provides a single flow of fluid through the system, that is, as the old fluid moves out, the new fluid moves in. It has been found that a single flow of fluid through the system oftentimes leaves some sludge and corrosion by-products

20 behind.

[0008] Therefore a need exists for a new and improved apparatus for flushing, replacing the fluid and bleeding hydraulic systems which overcomes the shortcomings of the prior art.

SUMMARY OF THE INVENTION

[0009] In accordance with the present invention, a new and improved servicing apparatus for flushing, replacing the fluid and bleeding hydraulic systems is disclosed. Hydraulic systems of the type serviceable by the apparatus of the present invention normally include a master cylinder which supplies fluid under pressure to a plurality of slave cylinders each of which has a bleed valve for bleeding air from the system. Most modern brake systems are provided with an Antilock Brake System (ABS) in the form of a computer controlled module which also has at least one bleeder valve. The servicing apparatus has a plurality of bleeder valve lines each of which is for connection to a different one of the bleeder valves and an independently operable shutoff valve is provided in each of these bleeder valve lines. The servicing machine also includes a master cylinder line which is connected to the top end of the master cylinder by means of a suitable adapter. A new fluid supply source and an old fluid holding vessel are provided in the servicing apparatus and both are coupled to a different one of a pair of inlet ports of a flow selector valve. The flow selector valve has an outlet port that is connected to the inlet of a pump and the flow selector valve is operable to direct fluid to the pump from either the new fluid supply source or the old fluid holding vessel. The pump is

preferably of the type which produces a pulsating output and supplies fluid under pressure to a two-position flow reversing valve. To initiate a servicing operation, the flow selector valve is positioned to direct fluid from the new fluid supply source vessel through to the two-position flow reversing valve which in turn directs the fluid under pressure through the master cylinder line to the top of the master cylinder. This causes the fluid to flow through the hydraulic system and out through the bleeder valves of the slave cylinders and into the servicing apparatus to fill the old fluid holding vessel. After initiation, the flow selector valve is operated to a first position wherein fluid from the old fluid holding vessel is directed through the hydraulic system and out through the bleeder valves as described above. Selective operation of the shutoff valves provided in the bleeder valve lines will allow fluid to flow out of all of the bleeder valves simultaneously or one at a time in any desired sequence. The fluid from the bleeder valves is directed through the flow reversing valve into a manifold which returns it to the old fluid holding tank. When the flow reversing valve is actuated to its second position, the fluid supplied by the pump will be directed under pressure through the hydraulic system in a direction that is opposite to the flow direction provided in the flow reversing valve's first position. In this manner, switching the flow reversing valve back and forth

between its first and second positions will move the old brake fluid in one direction through the hydraulic system and then in the reverse direction to flush the system.

5 **[0010]** The servicing apparatus may also include a vibration mechanism, a filter and a pressure port with a detachable nozzle. The vibration device is attachable to the master cylinder, and is movable to other components of the hydraulic system, to loosen contaminants in the system. The filter is used to remove
10 particulate contaminants from the old fluid that is being returned to the old fluid holding vessel for re-circulation through the hydraulic system during the flushing operation. The nozzle is a hand operated device for connection to the pressure port for initial cleaning of the master cylinder and for bench
15 bleeding the various components of the hydraulic system when the flow reversing valve is in the first position.

[0011] When flushing the hydraulic system has been completed, the flow selector valve is operated to shut off the flow from the
20 old fluid holding vessel and supply fluid from the new fluid supply source to the inlet port of the pump. With the flow reversing valve in either its first or second position, and the shutoff valves in the bleeder valve lines are opened in any desired sequence, the new fluid will be supplied to the hydraulic

system to replace the old fluid and simultaneously bleed the air from the system.

[0012] The servicing apparatus can be configured in various ways for detecting the completion of the fluid replacement and bleeding operations. In a first embodiment an optical sensor is provided for determining the clarity of the fluid being returned to the holding vessel from the hydraulic system and providing an indication when clean fluid is detected. To aid in such a determination, a fluid compatible dye may be injected into the replacement fluid at the beginning of the fluid replacement and bleeding operations. In a second embodiment, an ion-selective electrode is used to provide a suitable indication when the ions of a trace element , such as copper, are no longer detected in the fluid emerging from the hydraulic system. In still another embodiment, the new fluid supply is provided in pre-packaged containers that having an amount of fluid that is equal to or slightly greater than the fluid capacity of the hydraulic system being serviced.

[0013] In another embodiment, the apparatus is provided with three-way valves instead of shutoff valves to provide a cross-flushing capability of systems having interconnected components.

[0014] In the preferred embodiment, the pump and all of the valves of the servicing apparatus are electrically operated and are controlled by an electronic control unit. The electronic control unit is programable to change the operational sequence, timing and other functions of the servicing machine to suit the particular hydraulic system to be serviced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Fig.1 is a schematic diagram of a first embodiment of the servicing apparatus of the present invention which is shown
5 connected to a typical hydraulic system.

[0016] Fig.2 is a fragmentary perspective view showing a hand held nozzle being connected to a pressure port of the servicing apparatus for bench bleeding a typical master cylinder.

10 [0017] Fig.3 is a schematic diagram showing a fragmentary portion the servicing apparatus of the present invention which has been modified to include a trace element or dye injection system.

15 [0018] Fig.4 is a fragmentary schematic diagram showing a second embodiment the servicing machine of the present invention as having a first type of pre-packaged new fluid supply container.

20 [0019] Fig.5 is a fragmentary schematic diagram showing a third embodiment of the servicing machine of the present invention as having a second type of pre-packaged new fluid supply container.

[0020] Fig. 6 is a perspective view showing a vibrator demountably attached to a hydraulic system master cylinder.

[0021] Fig's. 7, 8, and 9 are schematic diagrams showing different types of hydraulic system that are serviceable by a second embodiment of the servicing apparatus of the present invention.

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[0022] Fig. 10 is a schematic diagram showing a fragmentary portion of the second embodiment of the servicing apparatus of the present invention for use in servicing hydraulic systems of the types shown in Fig's. 7, 8, and 9.

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DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0023] Referring more particularly to the drawings, Fig.1 shows a hydraulic system which is indicated generally by the reference numeral 10 and the hydraulic servicing apparatus of the present invention which is indicated generally by the reference numeral 12. The hydraulic system 10 is a schematically illustrated typical automotive braking system which includes: a master cylinder 14; an antilock brake system (ABS) modulator 16, an ABS control computer 18, and four slave cylinders 20, 22, 24 and 26. The ABS modulator 16 is provided with a bleeder valve 28 and each of the slave cylinders 20, 22, 24, and 26 has a bleed valve 30, 32, 34 and 36 respectively. It will be understood that not all automotive systems are the same, in some systems the ABS modulator is not used, and a proportioning valve (not shown) is used. In drum brake systems, the slave cylinders are in the form of wheel cylinders and in disc brake systems they are in the form of calipers.

[0024] The hydraulic servicing apparatus 12 is provided with five bleeder valve lines 38, 40, 42, 44 and 46 for demountable connection to the bleeder valves 28, 30, 32, 34 and 36 respectively. Five independently operable shutoff valves 48, 50, 52, 54 and 56 are provided with each being mounted in a different

one of the bleeder valve lines 38, 40, 42, 44 and 46. The shutoff valves 48, 50, 52, 54 and 56 are preferably in the form of solenoid operated two-way poppet valves each of which has a first port 58 connected to its respective one of the bleeder valve lines 38, 40, 42, 44 and 46 and a second port 60 which is connected to a manifold 62. The manifold 62 connects the second port 60 of each of the shutoff valves 48, 50, 52, 54 and 56 to a first fluid flow port 64 of a flow reversing valve 66.

[0025] The flow reversing valve 66 is in the preferred form of a solenoid operated two-position spool valve with its first position being shown in solid lines and its second position being shown in phantom lines. In addition to the first fluid flow port 64, the flow reversing valve 66 has a second fluid flow port 68, a first fluid return port 70, a second fluid return port 72 and a fluid inlet port 74. In the first position of the flow reversing valve 66, the first fluid flow port 64 is in communication with the second return fluid port 72, the second fluid flow port 68 is in communication with the fluid inlet port 74 and the first fluid return port 70 is blocked. In the second position of the flow reversing valve 66, the first fluid flow port 64 is coupled to the fluid inlet port 74, the second fluid flow port 68 is in communication with the first fluid return port 70 and the second fluid return port 72 is blocked. The second fluid flow port 68

of the flow reversing valve 66 is coupled by a master cylinder line 76 to the top of the master cylinder 14, and the master cylinder line may be provided with a pressure take-off port 77 for reasons which will hereinafter be described. The usual top closure (not shown) of the master cylinder 14 is removed while the flushing, fluid replacement and bleeding operations are being preformed and replaced by an adapter 78 that locates the distal end of the master cylinder line 76 in the reservoir of the master cylinder. The first and second fluid return ports 70 and 72 respectively of the flow reversing valve 66 are connected to a fluid return manifold 80 which, in the preferred embodiment, passes returning fluid through a filter 82 to an old fluid holding vessel 84. The filter 82 is for removing particulate contaminants which, if re-circulated through the hydraulic system, as will hereinafter be described in detail, could clog the internal filters (not shown) of the ABS modulator 16.

[0026] The old fluid holding vessel 84 is provided with a first outlet port 86 which is coupled by a suitable line 88 to a first inlet port 90 of a fluid selector valve 92. The fluid selector valve 92 has a second inlet port 94 and an outlet port 96, with the second inlet port 94 being coupled by a suitable line 98 to a new fluid supply source which in a first embodiment is in the form of a tank 100. The fluid selector valve 92 is in the

preferred form of a solenoid operated spool valve having a first position which is shown in solid lines and a second position which is shown in phantom lines. In the first position of the fluid selector valve 92, the first inlet port 90 is in
5 communication with the outlet port 96 and in the second position, the second inlet port 94 is in communication with the outlet port 96. The outlet port 96 of the fluid selector valve 92 is coupled by a line 101 to the inlet of a pump 102 which is driven by a suitable electric motor 104. When operating, the pump 102 will
10 draw fluid through the fluid selector valve 92 from either the old fluid holding vessel 84 or the new fluid supply vessel 100, depending on the position of the fluid selector valve 92, and the fluid will be supplied under pressure to the fluid inlet port 74 of the flow reversing valve 66. The pump 102 is preferably of
15 the type having a pulsating output, such as a piston pump or a gear-on-gear pump, to produce a surging fluid flow through the hydraulic system 10 to enhance the flushing and bleeding operations of the servicing apparatus 12. The desired pulsating fluid flow can also be accomplished by cyclically interrupting
20 power to the pump 102 or by cycling of the shutoff valves 48, 50, 52, 54, and 56 between their open and closed positions.

OPERATION

[0027] To begin the servicing operation, the bleed valve lines 38, 40, 42, 44, and 46 are connected to the bleeder valves 28, 32, 34, 36 and 38 respectively, and the bleeder valves are all opened. With the flow reversing valve 66 in its first position and the fluid selecting valve 92 in its second position, the pump 102 is operated to supply fluid from the new fluid supply tank 100 to the top of the master cylinder 14. That fluid will flow through the hydraulic system 10 and into the servicing apparatus 12 to fill the apparatus with fluid and when full, the flushing operation of the hydraulic system 10 can begin.

[0028] The flushing operation is started by actuating the fluid selector valve 92 to its first position and starting the pump 102. It does not matter if the flow reversing valve 66 is in the first or second position at the beginning of the flushing operation, however, since it was put into the first position by the operation described above, this description will be started with the flow reversing valve 66 in the first position. The pump 102 will draw fluid from the old fluid holding vessel 84 through the fluid selector valve 92 and supply that fluid under pressure to the inlet port 74 of the flow reversing valve 66. The fluid will move through the flow reversing valve 66 and out through the

second fluid flow port 68 thereof into the master cylinder line 76. The fluid supplied to the master cylinder line 76 will be directed into the master cylinder 14 and will move through the hydraulic system 10 in a manner determined by the bleeder line shutoff valves 48, 50, 52, 54 and 56. In Fig.1 the shutoff valve 56 is shown in the open position and all the others are in their normally closed positions. In this state, the fluid will flow only through the slave cylinder 20 to flush that cylinder and its associated lines. The fluid flowing through the open shutoff valve 56 will flow into the fluid return manifold 80 and from there through the filter 82 into the old fluid holding tank 84. After the fluid is moved through the hydraulic system 10 in this direction for a suitable length of time, the flow reversing valve 66 is switched to its second position which reverses the flow of fluid through the system. More specifically, the reversed fluid flow will move from the first fluid flow port 64 of the flow reversing valve 66, through the open shutoff valve 56, through the slave cylinder 20, through the ABS modulator 16 into the bottom of the master cylinder 14. The fluid entering the bottom of the master cylinder 14 moves out of the master cylinder through the master cylinder line 76 and is returned to the flow reversing valve 66. The fluid will move through the flow reversing valve 66 by entering through the second fluid flow port 68 and exiting through the first fluid return port 70

thereof. The fluid emerging from the first fluid return port 70 enters the fluid return manifold 80 and passes through the filter 82 into the old fluid holding tank 84. By cycling the flow reversing valve 66 back and forth between its first and second positions, fluid flow through the slave cylinder 20 and its associated lines is reversed to agitate the fluid and thus enhance the removal of sludge and corrosion by-products from that branch of the system. Such a flushing operation is repeated for each of the other slave cylinders and their associated lines and for the ABS modulator 16 by sequentially opening the shutoff valves 48, 50, 52, and 54. Opening the other shutoff valves 48, 50, 52, and 54 one at a time with the other shutoff valves in their normally closed positions, the slave cylinders 22, 24 and 26 as well as the ABS modulator 16 and their associated lines can be individually flushed in the manner described above.

[0029] When the flushing operation is complete, the old fluid holding tank 84 is emptied by opening a shutoff valve 106 which has an inlet port 108 and an outlet port 110 and is preferably a solenoid operated poppet valve. The inlet port 108 of the shutoff valve 106 is coupled to a second outlet port 112 of the old fluid holding tank 84 and the outlet port 110 of the shutoff valve 106 is coupled to the inlet of a waste fluid disposal tank 114. The outlet of the waste fluid disposal tank 114 is

preferably connected to a pump 116 which is operated by an electric motor 118 to empty the fluid from the old fluid holding tank 84. Alternatively, the fluid can be allowed to flow into the waste fluid disposal tank under the influence of gravity.

5 The waste fluid disposal tank 114 is provided with suitable fittings 120 at its inlet and outlet so that it 114 can be removed for fluid disposal purposes.

10 **[0030]** Replacing the old fluid in the hydraulic system 10 with new fluid is accomplished in a first embodiment by switching the fluid selector valve 92 to its second position to place it in communication with the new fluid supply vessel 100. The pump 102 is operated to draw the fluid out of the new fluid supply vessel 100 and move it through the flow reversing valve 66 into the
15 hydraulic system 10. The fluid can move through the flow reversing valve 66 in either position thereof, however, it is preferred that the flow reversing valve be in the second position. The reason for this is that any air which may be in the hydraulic system 10 will naturally tend to move upwardly and
20 by introducing the fluid into the system at its lowest points, the fluid flow will enhance the upward movement of the air and thereby simultaneously bleed the system.

[0031] The servicing apparatus 12 can be configured in various

ways for detecting the completion of the fluid replacement and bleeding operation. Detection can be accomplished by placing a fluid condition sensor 122 in the master cylinder line 76 and, in a first embodiment, that sensor is an optical sensor which

5 provides a suitable indication upon detection of clean new fluid in the line 76. The indication provided by the optical sensor can be an audio or visual signal or it can produce an electrical signal which terminates the operation of the apparatus 12. An optical sensor suitable for this purpose is identified as Model

10 No. TSL230, available from Texas Advanced Optoelectronic Solutions, Plano, Texas. This method can be enhanced by injecting an additive such as hydraulic fluid compatible dye into the system in a manner to be hereinafter described. In a second embodiment, the fluid condition sensor 122 is in the form of an
15 ion-selective electrode which provides an indication of the type described above when the metallic ions inherently present in the brake fluid being replaced are no longer detected in the fluid emerging from the hydraulic system 10. An ion-selective electrode suitable for this purpose is Model No. CU3005,
20 available from Weiss Research, Houston, Texas.

[0032] Reference is now made to Fig.3 which shows an additive injection sub-system 124 by which the fluid compatible dye, is introduced into the hydraulic system 10. The injection sub-

system 124 includes a solution container 126 having an outlet port 128 which is coupled to a shutoff valve 130 in the preferred form of a normally closed solenoid controlled poppet valve. The shutoff valve 130 has an outlet port 132 that is coupled to the inlet port 134 of a metering valve 136 in the preferred form of an adjustable orifice. The outlet of the metering valve 136 is connected to the line 101 that leads from the fluid selector valve 92 to the pump 102. When the shutoff valve 130 is actuated to its open position, the pump 102 will draw liquid from the solution container 126 and deliver it to the hydraulic system 10 in the manner hereinbefore described. Instead of using the adjustable orifice 136 to control the amount of dye injected into the system, controlling the time that the shutoff valve 130 is open will accomplish the same objective.

[0033] In a second embodiment, the old fluid from the hydraulic system 10 is replaced by supplying a known quantity of new fluid to the hydraulic system and when all of the known quantity of new fluid has been introduced, the replacement operation is terminated. The new fluid supply tank 100 of the hereinbefore described embodiment is replaced by either one of two pre-packaged containers which hold an amount of new fluid that is equal to, or slightly larger, than the capacity of the hydraulic system being serviced.

[0034] The first of the pre-packaged containers is seen in Fig. 4 to include a collapsible bag 138 having an outlet fitting 140 with the bag being placed in a housing 142. The housing 142 has a removable lid 146 with an inlet port 144 formed therein and a suitable air hose 148 is connected to the inlet port. The housing 142 is provided with an outlet opening 150 through which the outlet fitting 140 of the collapsible bag 138 protrudes. A residual pressure valve 152 is mounted on the distal end of the outlet fitting 140 of the bag 138 to prevent fluid leakage. Flow through the outlet fitting 140 will occur when the differential pressure across the valve 152 exceeds the residual pressure setting thereof. A line 154 connects the discharge end of the residual pressure valve 152 to the second inlet port 94 of the fluid selector valve 92. When the fluid selector valve is in its second position, as shown in solid lines in Fig.4, and the pump 102 is operated, a negative pressure is applied on the discharge end of the residual pressure valve 152. A positive pressure is applied to the inner end of the residual pressure valve 152 when the collapsible bag 138 is compressed upon the introduction of air under pressure into the housing 142. The combination of the negative and positive pressures on across the residual pressure valve 152 will provide the necessary differential pressure and the fluid within the collapsible bag 138 will be supplied to the hydraulic system 10.

[0035] Fig.5 shows the second type of pre-packaged container as being in the form a cartridge 156 having an outlet fitting 158 which extends through an opening provided in a cartridge retaining housing 160. A residual pressure valve 162 of the type
5 hereinbefore described is mounted on the distal end of the outlet fitting 158 to prevent fluid flow from the cartridge 156 until a predetermined differential pressure is applied across the residual pressure valve 162. A piston 164 is axially movable in the cartridge 156 to push the new fluid out through the outlet
10 fitting 158 and through the fluid selector valve 92 into the hydraulic system 10 as described above. A suitable ram 166, which can be pneumatic, hydraulic or electric, is employed to move the piston 164 axially in the cartridge 156.

15 [0036] The master cylinder line 76 is provided with the pressure take-off port 77 as hereinbefore mentioned and a hand held nozzle 168 is demountably connected to that port. The nozzle is shown in position to accomplish bench bleeding of the master cylinder 14. To accomplish such an operation, all the bleeder line
20 shutoff valves 48, 49, 50, 52 and 54 are de-energized to their normally closed positions to prevent fluid flow through the hydraulic system 10. Then the pump 102 is operated to supply fluid under pressure to the pressure take-off port 77 and to the nozzle 168. The nozzle is positioned to deliver the pressurized

fluid to one of the outlet ports of the master cylinder 14 with the other outlet port thereof being closed with a suitable plug 170. Fluid flowing into the master cylinder in this manner will force the air out of the master cylinder to complete the bench
5 bleeding operation. In brake systems that are in need of servicing, the master cylinders contain large amounts of sludge and contamination by-products and for that reason it is a common practice to drain the master cylinder and clean it prior to starting the servicing operation. The hand held nozzle 168 can
10 also be used to clean out the master cylinder by connecting it to the pressure take off port 77 and reversing the rotation of the pump 102 to supply a negative pressure to the nozzle.

[0037] Referring now to Fig.6 wherein a suitable vibrator 172 is
15 shown as an electrically operated unit that is demountably attached to the master cylinder 14, and is movable to other system components, to induce vibrations for loosening stubborn contaminants and putting them in suspension for flushing out of the system. A vibrator suitable for this purpose is commercially
20 available from Makita, La Mirada, California, Model No. VR251DWDE.

[0038] It has been found that a low, or no pressure area exists in the master cylinders of some hydraulic systems and no fluid

will flow in that area during flushing operations. When the hydraulic system is put in service after having been serviced as described above, fluid from that low, or no pressure area, will be circulated and contaminate an otherwise clean system. This is
5 overcome by the simple step of pushing the actuator rod 174, as indicated by the arrow 176 in Fig.6, to move the master cylinder piston (not shown) forward about one inch and holding it there during the flushing operation. This provides a fluid flow path through the otherwise stagnant area of the master cylinder to
10 flush the contaminants therefrom.

[0039] The hydraulic servicing apparatus 12 is preferably operated by an electronic control unit 178 which performs the switching operations and controls the timing of the servicing
15 machine 12. Power to the control unit 178 can be obtained from any suitable source such as a self-contained battery (not shown), connecting to the vehicle's power supply or by an external power supply such as a standard a 120 VAC source. The computer is programable so that the switching, timing and other functions of
20 the apparatus can be customized to service various types of hydraulic systems.

[0040] The hydraulic brake system 10 shown in Fig.1 is of the type wherein the slave cylinders 20, 22, 24, and 26 are connected

through the ABS modulator 16 to the master cylinder 14 by
separate brake lines. This is not always the case and reference
is now made to Fig's. 7, 8, and 9 which show different brake
systems 10a, 10b, and 10c, respectively, each having a different
5 brake line configuration.

[0041] The hydraulic brake system 10a of Fig. 7 shows the larger
compartment of a master cylinder 180 as having a single brake
line 182 connected to a line 184 which extends between the two
10 front slave cylinders 186 and 188. Similarly, a single line 190
extends from the smaller compartment of the master cylinder 180
and is connected to a cross line 192 which extends between the
two rear slave cylinders 194 and 196. Thus, the two front slave
cylinders 186 and 188 are in fluid communication with each other
15 and the two rear slave cylinders 194 and 196 are in fluid
communication with each other.

[0042] The hydraulic brake system 10b of Fig. 8 shows the larger
compartment of the master cylinder 180 as having two brake lines
20 198 and 200 extending therefrom with the line 198 being connected
to the front slave cylinder 186 and the line 200 being connector
to the other front slave cylinder 188. As in the brake system
10a of Fig.6, the system 10b of Fig. 8 has a single line 202
extending from the smaller compartment of the master cylinder 180

and is connected to a cross line 204 which extends between the two rear slave cylinders 194 and 196. In this brake line configuration, the two front slave cylinders 186 and 188 are in fluid communication with each other by virtue of their both being connected to the same compartment of the master cylinder 180, and the rear slave cylinders 194 and 196 are in fluid communication with each other by virtue of the cross brake line 204.

[0043] The hydraulic brake system 10c of Fig. 9 shows a first brake line 206 extending from the master cylinder 180 to the front slave cylinder 186 and a diagonal brake line 208 extending from the front slave cylinder 186 to the rear slave cylinder 196. Thus, the front cylinder 186 is in fluid communication with the rear slave cylinder 196. A second brake line 210 extends from the master cylinder 180 to the other front slave cylinder 188 and a diagonal brake line 212 extends from the front slave cylinder 188 to the other rear slave cylinder 194. Therefore, the front and rear slave cylinders 188 and 194, respectively, are in fluid communication with each other.

[0044] In hydraulic brake systems of the type wherein pairs of the slave cylinders are in fluid communication with each other, such as the systems 10a, 10b, and 10c, discussed above, a brake flushing technique known as cross-flushing can be advantageously

employed. Cross-flushing is accomplished by injecting fluid into one of the two cylinders that are in fluid communication with each other so it flows through both cylinders and the associated brake line to flush that portion of the system. The advantage of cross-flushing is that the fluid flow restrictions inherent in master cylinders and ABS modulators are eliminated resulting in a significant increase in the volume and velocity of the flushing fluid to quickly and effectively purge contaminants from that portion of the hydraulic system. This same technique can be used in bleeding operations for efficiently removing air from the hydraulic system.

[0045] Reference is now made to Fig. 10 wherein a fragmentary portion of a second embodiment of the hydraulic servicing apparatus of the present invention is indicated generally by the reference numeral 14a, with this embodiment being configured to accomplish the above describe cross-flushing technique on the hydraulic system 10a. The solenoid operated two-way poppet valves 50, 52, 54 and 56 of the previously describe system 14 have been replaced by solenoid operated three-way poppet valves, three of which are shown and indicated by the reference numerals 214, 216 and 218. It will be understood that each of the three-way poppet valves is connected to a different one of the slave cylinders and the following detailed description of the

connection and operation of the poppet valves 214 and 216 also applies to the other poppet valves. The three-way poppet valves 214 and 216 each have a bleeder valve line 220 and 222, respectively, extending from their first ports 224 to the bleeder valves 226 of the slave cylinders 194 and 196 of the hydraulic system 10a. Second ports 228 of the valves 214 and 216 are connected to the manifold 62 which is in fluid communication with the first fluid port 64 of the flow reversing valve 66. The third port 230 of each three-way poppet valve is connected to a collection manifold 232 which is in fluid communication with a first port 234 of a shutoff valve 236, and the second port 238 of the shutoff valve 236 is connected by a fluid return line to the fluid return manifold 80. The shutoff valve 236 is preferably a solenoid operated two-way poppet valve and its function will herein after be described.

[0046] A Cross-flushing operation on the two slave cylinders 194, and 196 is accomplished with the flow reversing valve 66 in its second position (shown in solid lines in Fig.10) so that fluid supplied by the pump 108 is directed through the flow reversing valve 66 and the manifold 62 to the second ports 228 of the three-way poppet valves 214, 216, and 218 and the fourth poppet valve(not shown). The poppet valve 214 is shown in a first position wherein the first and second ports 224 and 228 are in

fluid communication with each other and the third port 230 is blocked. The other three way poppet valves 216 and 218 are in the second position wherein the first and third ports 224 and 230 are in fluid communication with each other and the second ports 228 are blocked. Since the second ports 228 of all except the poppet valve 214 are blocked, the fluid supplied through the manifold 62 will flow only into the second port 228 of the valve 214 and out through its first port 224. Fluid emerging from the port 224 of the valve 214 is directed by the bleeder valve line 220 into and through the slave cylinder 194 and through the cross-line 192 into the slave cylinder 196. Since the master cylinder 180 has a relatively high resistance to fluid flow, fluid in the cross-line 192 will take the path of least resistance and will flow and directly and sequentially through the slave cylinders 194 and 196. The fluid will exit the slave cylinder 196 through the bleeder valve line 222 and flow into the first port 224 of the three-way poppet valve 216. With the poppet valve 216 in the second position, fluid will flow out through its third port 230 into the manifold 232 and through the shutoff valve 236 into the fluid return manifold 80 into the holding vessel 84.

[0047] The shutoff valve 236 is open position during cross-flushing operations to provide a flow path for fluid returning

from the hydraulic system being serviced. When the shutoff valve 236 is actuated to its closed position, the third port 230 of the three-way poppet valves 214, 216, 218 and the fourth valve (not shown), will be blocked and those valves will then function as two way poppet valves. Therefore, when the shutoff valve 236 is closed, the apparatus 14a will function in the manner hereinbefore described with reference to the apparatus 14.

[0048] While the principles of the invention have now been made clear in illustrated embodiments, many modifications will be obvious to those skilled in the art which do not depart from those principles. The appended claims are therefore intended to cover such modifications within the limits only of the true spirit and scope of the invention.